ELEC 566 : Nanophotonics and Metamaterials

Instructor
Guru Naik
Electrical & Computer Engineering
Office: Brockman 337
Email: guru@rice.edu
Course Type: Lecture

Credits: 3

Course schedule: Monday and Wednesday 4:30-5:45 PM in AEL A121

Office hours: Monday 3-4 pm + by appointment

Course description
In the past decade, plasmonics and metamaterials have tremendously expanded the scope and applications of Nanophotonics by allowing unprecedented control on the light flow. In this course, the principles governing the operation and design of plasmonic and metamaterial devices will be discussed. The course will cover the basics of light-matter interaction, and discuss the operation and design of photonic crystal, plasmonic and metamaterial devices with an emphasis on metamaterials. The course will also discuss aspects of nanofabrication used in building nanophotonic devices, and conclude with applications of various meta-devices and upcoming research topics.

Objective
The course aims at teaching the fundamental principles that govern the operation of meta-devices and familiarize students with current research topics.

Student Learning Outcomes
By the end of the course, the students should be able to answer the following:
How does light interact with matter at different scales?
What are metamaterials?
How are meta-devices created and what are their applications?

Pre-requisites
ELEC 262 OR PHYS 201 OR equivalent sophomore or higher level courses.
The course is open to graduate students from any department with a background in electromagnetics and optics. Undergraduate students interested in the course are encouraged to contact the instructor.

Topics
1. Light-matter interaction
    1.1. Local field approximation, Constitutive relations, Dielectric function, Kramers-Kronig relationship
    1.2. Two level system, Lorentz model
    1.3. Metals, Semiconductors and Dielectrics
    1.4. Scattering from planar interfaces, microstructures and nanostructures, lumped element approximation
    1.5. Composite materials, effective medium theory

2. Introduction to Photonic Crystals
    2.1. Electromagnetic wave in periodic potential
    2.2. Applications of photonic crystals for omni-directional reflection, sharp waveguide bends, light localization, super-prism effects and photonic crystal fibers
3. Plasmonics
    3.1. Light interaction with 0, 1 and 2 dimensional metallic nanostructures
    3.2. Guiding and focusing of light (below the diffraction limit)
4. Metamaterials
    4.1. Electric and magnetic metamaterials
    4.2. Negative refractive index
    4.3. Super-lens and hyper-lens
    4.4. Transformation optics and invisibility cloak
    4.5. Metasurfaces and phase engineering
5. Nanofabrication of optical meta-devices
    5.1. Lithography, lift-off, wet and dry etching
    5.2. Colloidal synthesis and self-assembly
    5.3. Nano-imprinting
    5.4. Direct laser writing
6. Application of meta-devices in imaging, information processing, sensing, medicine and energy

Text Books

The books mentioned in the following can serve as references and not necessary for successful completion of the course or solving assignments/exams. The course material is expected to be sufficient.

- **Optical Metamaterials: Fundamentals and Applications** (Wenshan Cai and Vladimir Shalaev, Springer 2010).
- **Absorption and Scattering of Light by Small Particles** (Craig F. Bohren and Donald R. Huffman, Wiley 1998) - chapters 1-5, 9, 10, 12, 13
- **Tutorials in Metamaterials** (Mikhail A. Noginov and Viktor A. Podolskiy, CRC press 2012) - chapters 2, 4, and 9

Grading

Your final grade will be determined based on the following weights:
Homework (4 assignment modules) – 4 x 7.5% = 30%
Quizzes (2) – 2 x 10% = 20%
Mid-term exam – 20%
Final presentation – 25%
Participation in class (Instructor discretion) – 5%
Late submission of homework assignments may attract penalty. Assignments received after solutions are posted will not be graded.

Honor Code Policy:

Homework assignments:
You may use your text, course notes, and any other reference materials. You may discuss problems, general strategies, with other people (in the course or not). However, you must turn in your own copy of the solutions. You should avoid using the completed work of other students, old homework solutions, and old exams and solutions. You should understand and be able to recreate any part of the solutions on your own.

Exam/quiz:
Exam must be completed independently. Quizzes will be conducted during the class and the rules of each quiz will be announced in the previous class.

Absence policy:
Class attendance is required during mid-term exam, quizzes and final presentation at the end of the semester. Students are not required to attend the lectures, but they will be responsible for the material covered during the missed lectures. The slides presented during the class will be available on the course website, and it is the responsibility of the student to make up for the missed lecture contents.

Students with Disabilities:
Any student with a documented disability seeking accommodations in this course should contact the instructor after class or during office hours. Additionally, please contact Disability Support Services in the Allen Center.

Updates to the Course:
Information contained in this course syllabus, other than the absence policies, may be subject to change with reasonable advance notice as appropriate.